SIXTH QUARTERLY REPORT

DTPH56-14-H-00008
"Definition of Geotechnical and Operational Load Effects on Pipeline Anomalies"

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1.0 Technical Status

1.1 Technical Progress

Task 1: - Project Kickoff

The meeting discussion and actions were documented in meeting minutes posted to the project website.

Task 2: Documentation of Model Validation

The project team completed preparation of the model validation report from previous work describing the numerical model that will support this project and its capabilities as simulation tool. The report was submitted and posted to the project website.

Task 3: Model Development and Demonstration

Objective: Describe and demonstrate the simulation process to support discussion and confirmation of the project scope of work.

Scope: The scope of this task was to complete three subsidence and three lateral soil movement simulations with differing pipe geometries, soils, materials and operating conditions to illustrate the impact of the problem parameters on the analysis results.

Activities:

The completed report describing the geotechnical simulation process and results of three subsidence and three lateral soil movement simulations was posted to the DOT website. The results of the finite element analyses were interpolated, to produce an envelope defining the combination of ground displacement and width where the pipe was safe and not safe. Failure of "not safe pipe" was presumed to occur if the axial (tensile and/or compressive strains) at any location exceeded strain limit defined from BS 7910, CSA-Z662 and PRCI 2004.

Peers Review and the Analysis Results: In order to be able to react and confirm the project scope of work, Peers review meeting was held on May 27, 2015 to discuss the results and observations available at this time.

A presentation was made by BMT which was used as the basis for discussion. The presentation included the purpose of the Peers review meeting, the objective of the project, deliverables and goals, the project plan and communication plan.

The presentation documents were posted to the project website.

Task 4: Modeling of Subsidence Hazard

Objective: Complete a sensitivity study to define the relationship between problem parameters and the pipe strains developed in soil subsidence events and identify trends.

Scope: The scope of this task is to develop and simulate a range of pipe soil subsidence scenarios considering differing pipe geometries, soils, pipe materials and operating conditions to define the impact of the problem parameters (e.g., depth of subsidence, subsidence length, surcharge) on the analysis results. It is expected that the modeling process will describe pipeline response in terms of axial and bending stresses and strains (or loads), pipe deformation and potential for buckling/wrinkling. These sample modeling results will be used to develop an empirical relationship between the pipe, pipeline, geotechnical and operating parameters affecting peak pipe strains.

Activities:

A sensitivity analysis is being carried out to evaluate the effects of the some key parameters, including:

Pipe diameters and wall thickness or D/t ratio:
30”/0.5”=60, 30”/0.375=80, 30”/0.312=96,
24”/0.218”=110, 24”/0.25”=96, 24”/0.312”= 77
20”/0.218 =92, 20”/0.25=80, 20”/0.312=64,
16”/0.25=64, 20”/0.312=51, 16/0.218= 73

- Pipe Grade: X52 and X70
- Subsidence Widths: Subcritical, critical and supercritical
- Subsidence: Pit Subsidence and Sag subsidence

Sample Results:

- Figure 2 shows an example of predicted subsidence basin along the pipeline for critical subsidence width. This subsidence results in axial soil movement and strains in the soil.

- Figure 3 through 5 plot the surface subsidence profile, pipeline profile and pipeline axial strains distribution at different clock position (6 and 12 o’clock) along the length of the pipeline. The results presented in these Figures are for 24-inch pipe, with D/t ratio of 96 and material grade X52 considering subcritical, critical and Super-critical extraction width (W/H ratio of 0.75, 1.5 and 3).

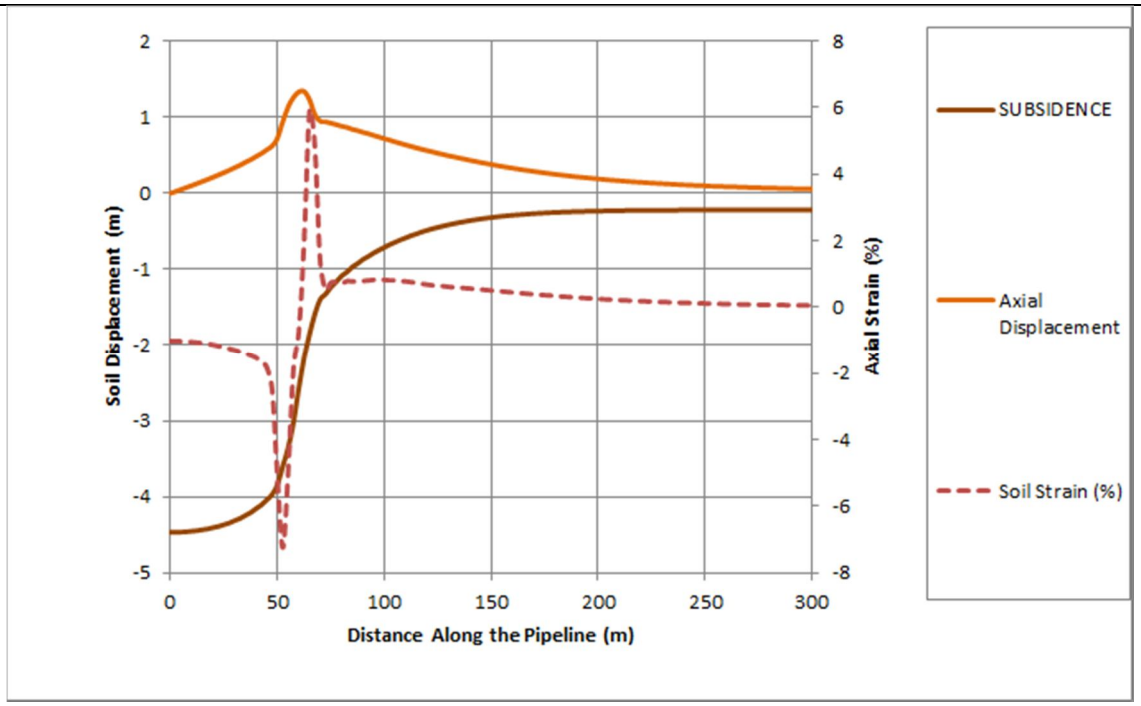

Figure 2: Predicted Subsidence Profile along the Pipeline and Maximum Axial soil displacement and Tensile Strains in the Soil

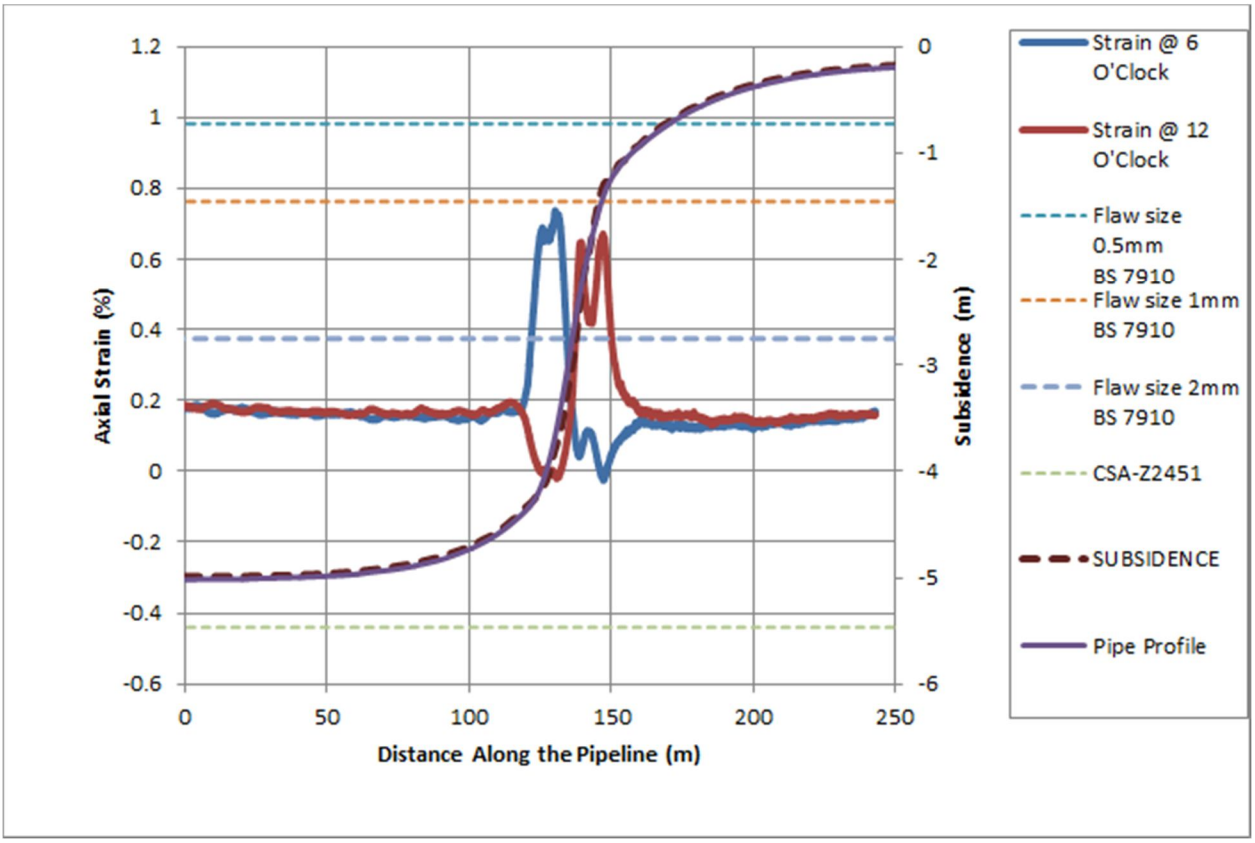

Figure 3: Predicted Pipeline, Subsidence Profiles and Maximum Tensile Strains in the Pipe in for Mining Depth Ratio (W/H=3)

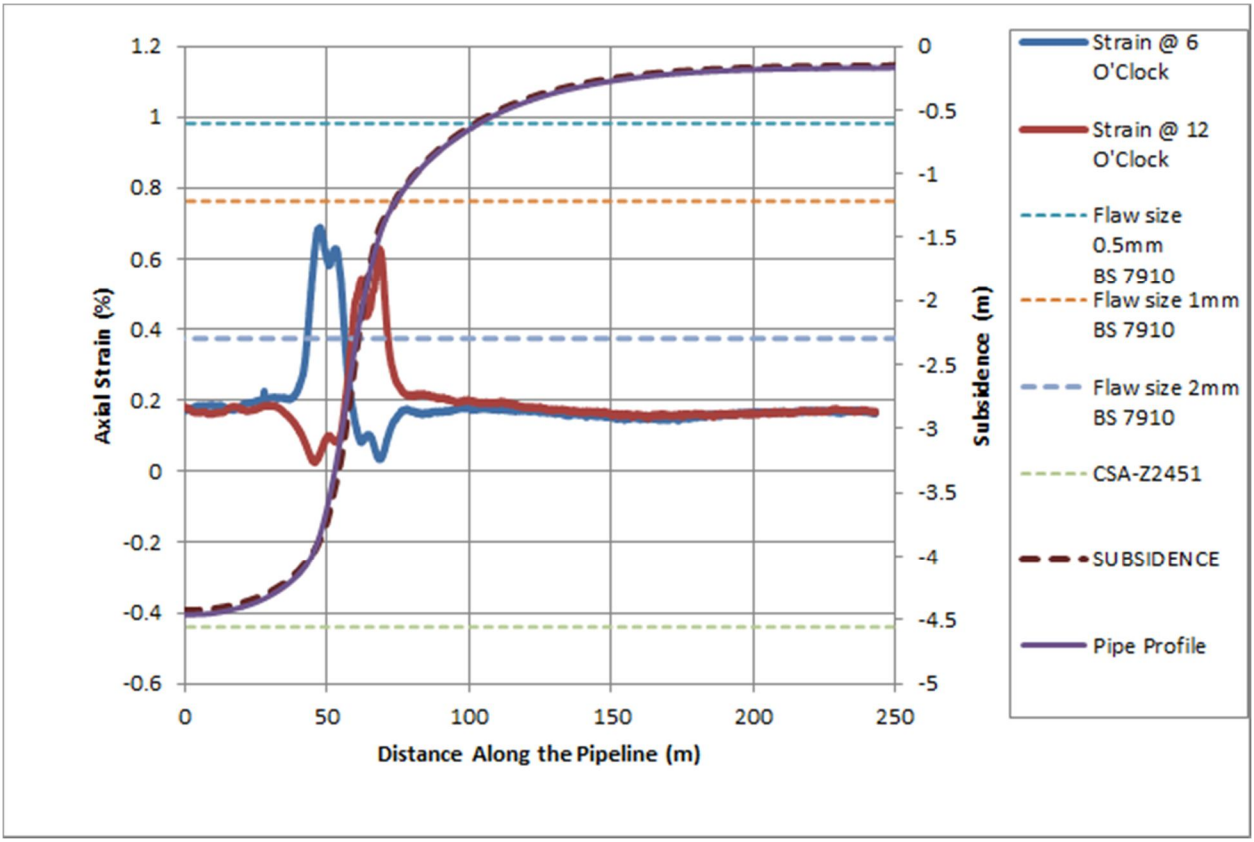

Figure 4: Predicted Pipeline, Subsidence Profiles and Maximum Tensile Strains in the Pipe in for Mining Depth Ratio (W/H=1.5)

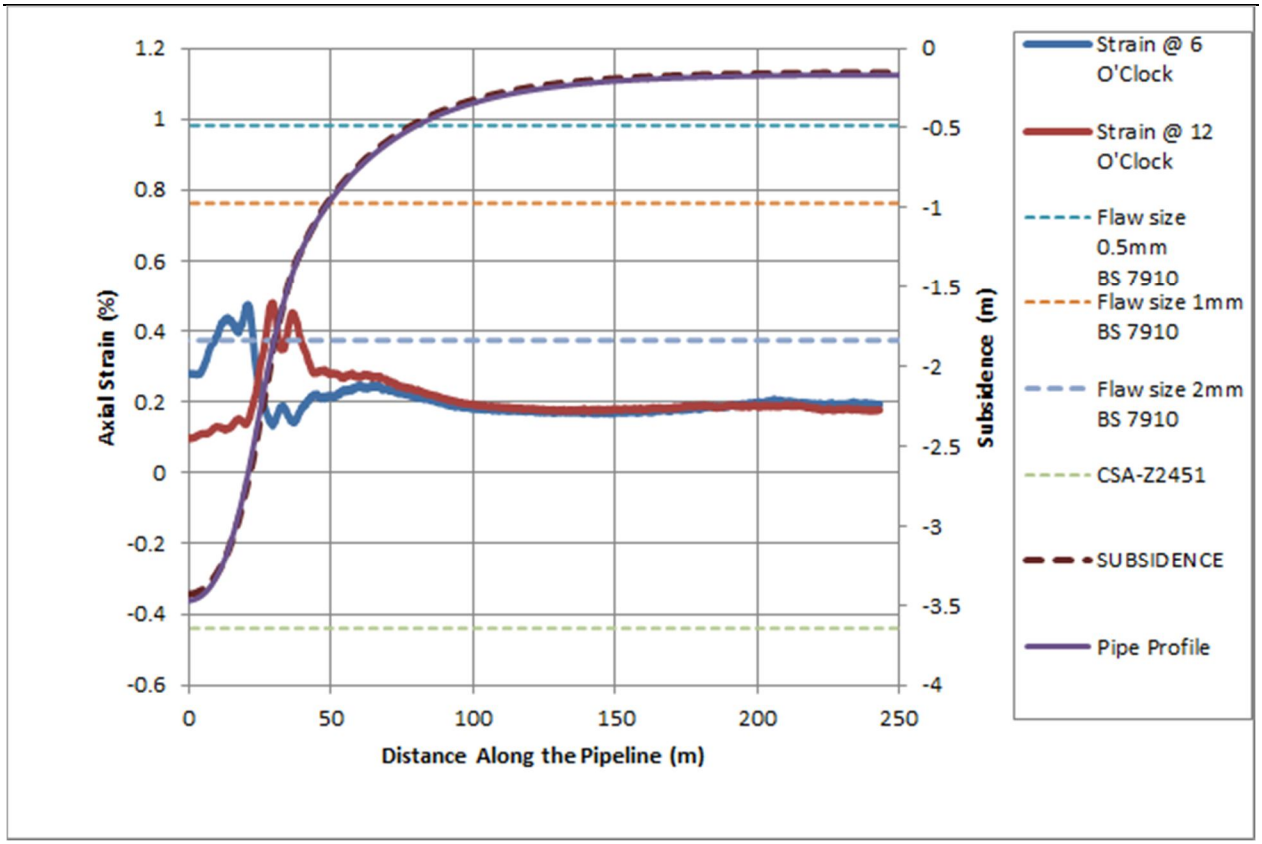

Figure 5: Predicted Pipeline, Subsidence Profiles and Maximum Tensile Strains in the Pipe in for Mining Depth Ratio (W/H=0.75)

Task 5 –Modeling of Lateral Soil Movement

Objective: Complete a sensitivity study to define the relationship between problem parameters and the pipe strains developed in lateral soil movement events and identify trends.

Scope: The scope of this task is to develop and simulate a range of pipe soil lateral movement scenarios considering differing pipe geometries, soils, pipe materials and operating conditions to define the impact of the problem parameters (e.g., soil movement width, surcharge) on the analysis results. It is expected that the modeling process will describe pipeline response in terms of axial and bending stresses and strains (or loads), pipe deformation and potential for buckling/wrinkling. These sample modeling results will be used to develop an empirical relationship between the pipe, geotechnical and operating parameters affecting peak pipe strains.

Activities:

A sensitivity analysis is being carried out to evaluate the effects of the some key parameters, including:

- Pipe diameters and wall thickness or D/t ratio:
  30”/0.5”=60, 30”/0.375=80, 30”/0.312=96,

24”/0.218”=110, 24”/0.25”=96, 24”/0.312”= 77
20”/0.218 =92, 20”/0.25=80, 20”/0.312=64,
16”/0.25=64, 20”/0.312=51, 16/0.218= 73

- Pipe Grade: X52 and X70
- Landslide width: Gourd movement width ranging between 5 to 100m
- Angle between the landslide and the pipeline: two loading scenario were considered lateral ground movement (perpendicular to the pipeline) and ground movement at crossing angle of 45^0. Note that the focus of the project is on lateral ground movement. The Project Team will run some cases considering two crossing angle (e.g. 45^0 and 65^0) to demonstrate the significance of at ground movement at crossing angle.

Sample Results:

Figure 6 through Figure 8 show the true axial strain at 3’oclock and 9 o’clock position along the pipeline in the 24-inch pipeline , with D/t ratio of 96 and material grade X52. The results in Figure are for ground movement width of 5 m, 10 and 15 m considering a soil movement of 1.9 m.

The analysis has demonstrated that pipeline parameters and operating loading have a significant effect on the pipeline response and integrity. For a given pipe geometry and operating conditions, there is a critical lateral soil movement width that maximizes pipe bending moments and strains. The critical soil movement width is about 5 m for the 24 inch pipeline. Figure 9 shows the pipe deformation considering ground movement width of 5m; the pipe exceeds the compressive strain limit and buckle/wrinkle. A sensitivity analysis is being carried and more details will be provided in the next progress report.

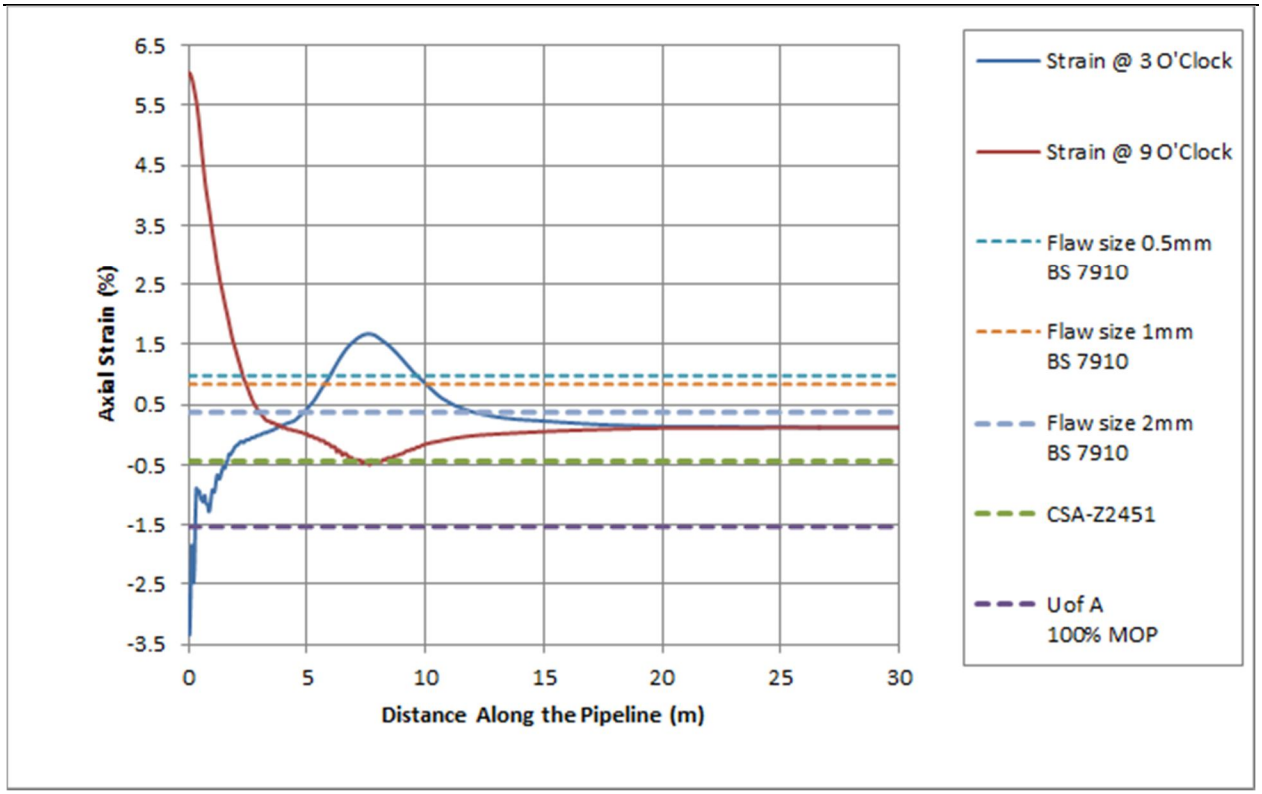

Figure 6: Maximum Axial Tensile & Compressive Strains in the Pipeline (Ground movement width of 5 m) Considering Ground Displacement of 2 m

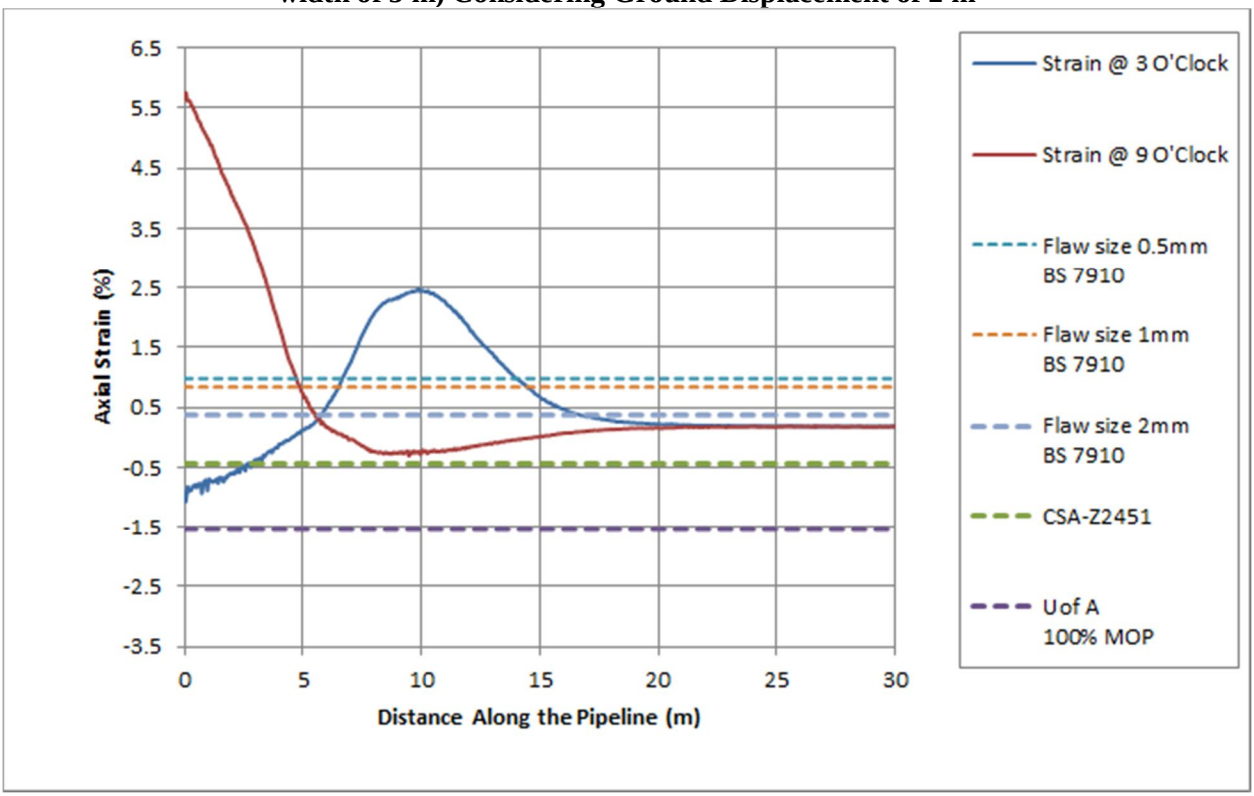

Figure 7: Maximum Axial Tensile & Compressive Strains in the Pipeline (Ground movement width of 10 m) Considering Ground Displacement of 2 m

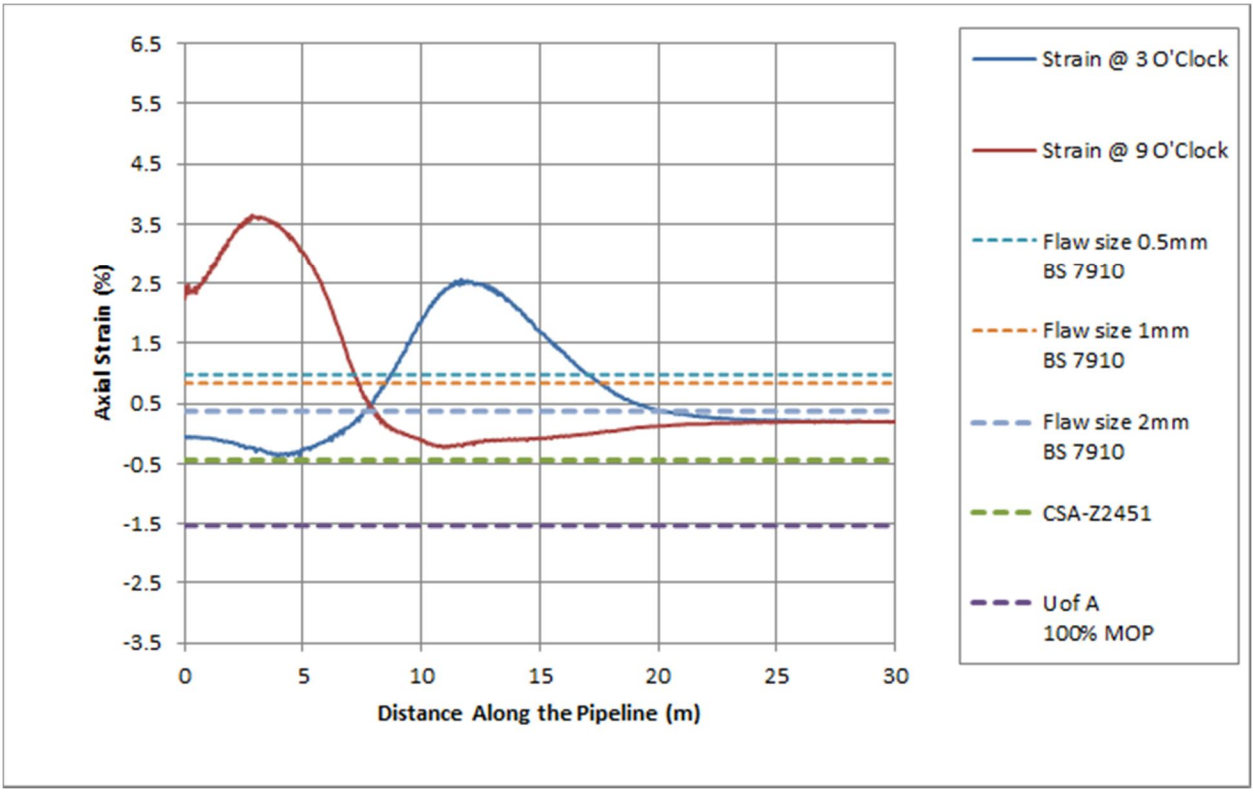

Figure 8: Maximum Axial Tensile & Compressive Strains in the Pipeline (Ground movement width of 15 m) Considering Ground Displacement of 2 m

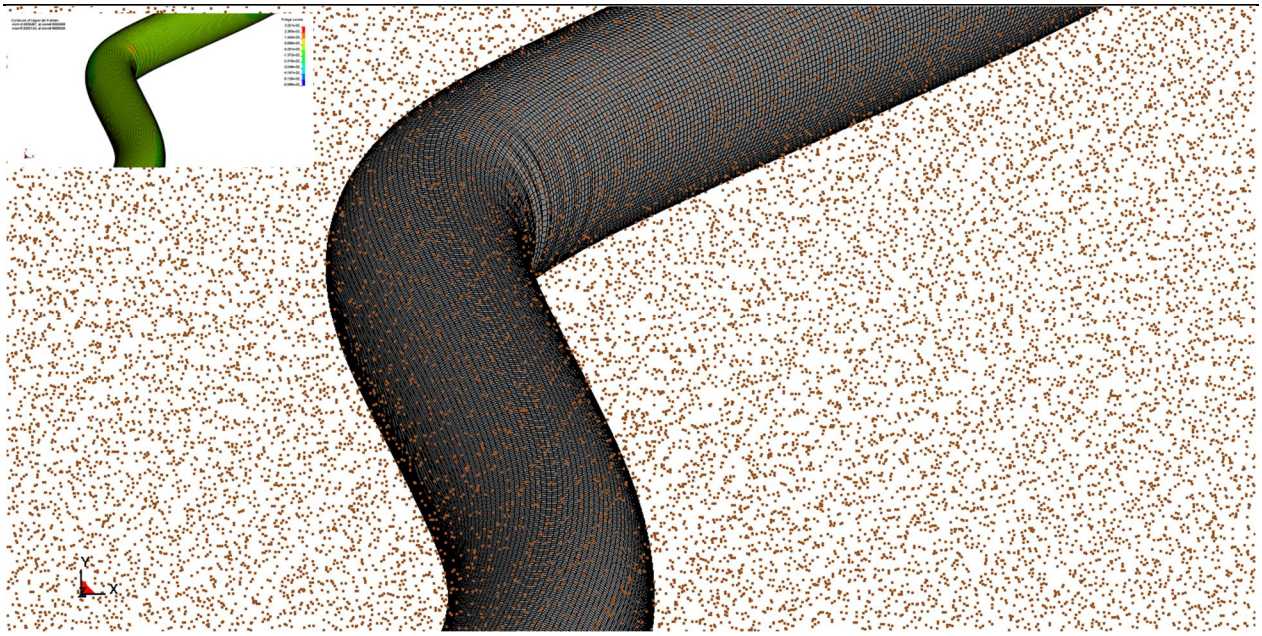

Figure 9: Pipeline Deformation (Ground movement width of 15 m) Considering Ground Displacement of 2 m

Task 6: Project Management and Reporting

The work completed in this task in the last quarter included:

- The project team prepared project status reports
- Advisory Panel review meeting and presentation

1.3 Plans for Future Activity

Over the next 30-60 days, the following activities will be conducted:

Task 4: Modeling of Ground Subsidence

A sensitivity analysis is being carried to define "safety envelopes" for the case where pipe is loaded by ground subsidence. Safety envelopes were defined with respect to the combination of the panel width to mining depth ratio (W/H) for various soil strengths, pipe geometry (D/t), steel grade, pipe to soil coefficient of friction, subsidence widths, Subsidence type (sag and pit subsidence).

The project team will complete and submit a report describing the geotechnical process and results in support of an information and technical direction progress meeting.

Task 5 –Modeling of Lateral Soil Movement

A sensitivity analysis is being carried to define "safety envelopes" for the case where pipe is loaded by lateral ground movement. Safety envelopes were defined with respect to the combination of ground displacement width for various soil strengths, pipe geometry (D/t), steel grade, pipe to soil coefficient of friction, landslide widths landslide direction to the pipeline (lateral and at crossing angle).

The project team will complete and submit a report describing the geotechnical process and results in support of an information and technical direction progress meeting.

Task 7: Project Management and Reporting

The project team will complete and submit the upcoming required monthly and quarterly reports.